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New records of *Phyllanthus* (Phyllanthaceae) for the Brazilian northeastern Atlantic Forest, and re-collection of the rare species *Phyllanthus carvalhoi* G.L. Webster

Alicia Marques Torres[1], Sarah Maria Athiê-Souza[2], Jone Clebson Ribeiro Mendes[1], Wesley Patrício Freire de Sá Cordeiro[1], Margareth Ferreira de Sales[1]

1 Programa de Pós-graduação em Botânica, Departamento de Biologia, Universidade Federal Rural de Pernambuco, 52171-900, Recife, PE, Brazil. **2** Universidade Federal da Paraíba, Centro de Ciências Exatas e da Natureza, Departamento de Sistemática e Ecologia, 58051-900, João Pessoa, PB, Brazil.

Corresponding author: Sarah Maria Athiê-Souza, sarah_athie@yahoo.com.br

Abstract

During a taxonomic study of Phyllanthaceae in northeastern Brazil, new occurrences for three species of *Phyllanthus* were recorded: *P. augustinii* Baill., *P. hyssopifolioides* Kunth, and *P. riedelianus* Müll. Arg. Diagnoses, distributional information, conservation statuses of these species, as well as comments on their affinity, are provided here. Additionally, the rare *Phyllanthus carvalhoi* G.L. Webster was collected. It is endemic to the Atlantic Forest in Bahia state, and we provide an updated morphological description, conservation status, photographs, and illustrations.

Keywords

Endangered species, Bahia, endemism, taxonomy.

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Introduction

The Atlantic Forest domain in Brazil stands out among biodiversity hotspots due to its high degree of endemism, with approximately 8,000 unique species (Myers et al. 2000). Much of that biodiversity has been lost, however, as a result of widespread habitat devastation and forest fragmentation, leaving only 7–12% of its original cover and causing many rare and endemics species to go extinct the extinction of many rare and endemic species (Lagos and Muller 2007; Mittermeier et al. 2004). In northeastern Brazil, the Atlantic Forest is mainly along the coast, extending from eastern Rio Grande do Norte to southern Bahia (Barbosa 2004). Deforestation rates are much more severe in this region of the country, where only 1–2% of the original forest cover remains, mainly in southern Bahia (CEPF-Critical Ecosystem Partnership Fund 2001)

Phyllanthus L. has a cosmopolitan distribution, and is considered the most diverse genus in Phyllanthaceae, with approximately 800 species, of which over 200 are recorded for the Neotropics; 88 species occur in Brazil, in all vegetation types (Webster 2002; Secco et al. 2015). The Atlantic Forest encompasses the greatest diversity of the genus (47 spp.), followed by the Cerrado (40 spp.) (Secco et al. 2015). Among the approximately 25 species

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endemic to the Atlantic Forest, almost 10 are found exclusively in the northeastern region of Brazil (e.g., *P. carvalhoi* G.L. Webster) (Secco et al. 2015). The genus is mainly characterized by a herbaceous to subshrub habit, with phyllanthoid or non-phyllanthoid branching, unisexual monochlamydeous flowers, with a nectariferous disk usually segmented in staminate and entire in pistillate flowers, and trigonal seeds that are usually ornamented (Silva and Sales 2007).

During a taxonomic study of Phyllanthaceae in the Atlantic Forest of northeastern Brazil, almost 2,850 specimens were consulted and the geographical distribution of all species of the genera were analyzed. Through field expeditions, we encountered a second specimen of *P. carvalhoi*, which was only known from a single sample collected 36 years ago. Additionally, *P. augustinii* Baill., *P. hyssopifolioides* Kunth, and *P. riedelianus* Müll. Arg. were recorded during that survey for the first time in northeastern Brazil. Although the Brazilian Atlantic Forest has been one of the most intensively studied domains due to its high biodiversity (Mittermeier et al. 2004; Lagos and Muller 2007), there are still gaps in our knowledge of it. The findings reported here reinforce the need to expand studies and collections in the region as well as draw attention to the importance of defining public policies that can avoid the extinction of rare and endemic species in the Brazilian northeastern Atlantic Forest.

Methods

Phyllanthaceae specimens from AJU, ALCB, ASE, CEPEC, EAN, HUESB, HUEFS, HST, IPA, JPB, MAC, PEUFR, RN, UFP, UFRN, HURB, and TEPB (acronyms according to Thiers 2019) were analyzed, identified and studied. At the same time, we made collections in several Atlantic Forest formations in northeastern Brazil, with priority given to rare and endemic species of the region and poorly sampled sites.

To make and confirm the identifications, we consulted the specialized bibliography (Webster 2002; Silva and Sales 2007, 2008; Martins et al. 2014, 2017) and made comparisons with dried samples and images of specimens in MBM, NY, MBML, and UEC. We confirmed identifications by analyzing images of types in CEPEC, DAV, P, and NY. The terminology used in the morphological description follows Radford et al. (1974), complemented with recommendations from Silva and Sales (2007) and Webster (2002). Our comments on species' distributions were based on exsiccate labels, the specialized literature (Webster 2002; Silva and Sales 2007, 2008; Martins et al. 2014, 2017), and the Brazilian Flora (Secco et al. 2015).

The conservation statuses of the species were reevaluated according to the IUCN methodology and criteria (IUCN 2012) using the web tool Geocat (http://geocat.kew.org/) and following Bachman et al. (2011). Maps were prepared using QGIS v. 2.3 and based on geographic coordinate data recorded on the herbarium specimens' labels or estimated from locality data. The classification of vegetation types follows IBGE (2012). Vouchers were deposited in PEUFR (Universidade Federal Rural de Pernambuco, Brazil).

Results

***Phyllanthus augustinii* Baill.**, Adansonia 5: 354. 1865.

Type. Brazil: Rio de Janeiro. 1816–1821, A. de Saint–Hilaire 743 (holotype, P00608935!).

New records (Fig. 1A). Brazil. Bahia: Andaraí, Alagados Marimbus: 12°45′55″S, 041°18′52″W, 07 Dec. 2012, *E. Melo et al. 11809* (HUEFS 193209). Pernambuco: Vicência, mata do engenho canavieiras: 07°37′54″S, 035°19′13″W, 26 Aug. 2002, *M.J. Silva 201* (PEUFR 47467); *M.J. Silva 202* (PEUFR 43482); *M.J. Silva 203* (PEUFR 43476); *M.J. Silva 205* (PEUFR 43477); *M.J. Silva 206* (PEUFR 43478); *M.J. Silva 208* (PEUFR 43479); *M.J. Silva 209* (PEUFR 43480); Nazaré da Mata: 07°44′30″S, 035°13′46″W, 20 Jan. 1955, *J.C. Moraes s.n.* (PEUFR 47575).

Identification. This species can be distinguished from other members of the genus for its subshrub habit, asymmetrical leaf bases, an obcordate staminate disk, pistillate flowers with a long pedicel (2–3 cm long) and long styles (1–1.5 mm long). It resembles *P. niruri* in the shape and asymmetry of the leaves, staminate and pistillate flowers with five oboval sepals, and three free stamens. It can be differentiated from *P. niruri,* by the obtriangular staminate disk (vs obcordate in *P. augustinii*), short-pedicelate pistillate flowers 0.3–0.4 cm long (vs 2–3 cm long), and short styles up to 0.5 mm long (vs 1–1.5 mm long).

Habitat and distribution. Endemic to Brazil, it has been recorded only for the Atlantic Forest in the states of Espírito Santo and Rio de Janeiro (Secco et al. 2015). In the study area, *P. augustinii* is only known from a few populations, all in ombrophilous forests in flooded areas in the Atlantic Forest. The flowering period was from January to August in the study area.

Conservation status. *Phyllanthus augustinii* was previously classified as Threatened, with only a single collection besides the type collection, both outside established conservation areas (Martins et al. 2014). We expanded its distribution in this study with the discovery of two more populations in the Atlantic Forest of Pernambuco state, and a population in the Atlantic Forest of Bahia state, both in northeastern Brazil. Following IUCN (2012) criteria, the species is designated as VU B1ac(i,ii); D1. No specimens were found in protected areas.

***Phyllanthus carvalhoi* G.L. Webster**, Lundellia (5): 5. 2002.
Figures 2, 3

Type. Brazil: Bahia: Itamaraju, Fazenda Pau-Brasil, mata higrófila sul Baiana, 160 m, 3 Jul. 1983, *A.M. Carvalho, R. Callellas & L.A. Mattos Silva 2022* (holotype,

CEPEC 33693!; isotypes DAV00688457!, NY153084!).

New records (Fig. 1A). Brazil. Bahia: Itamaraju, fazenda Pau-Brasil, 16°58′06.654″S, 039°34′08.424″W, 19 May 2019, *A. M. Torres 213* (PEUFR 55078).

Description. Subshrub 50–70 cm tall, monoecious. Phyllanthoid branching. Branches 10–13 cm long, cylindrical,

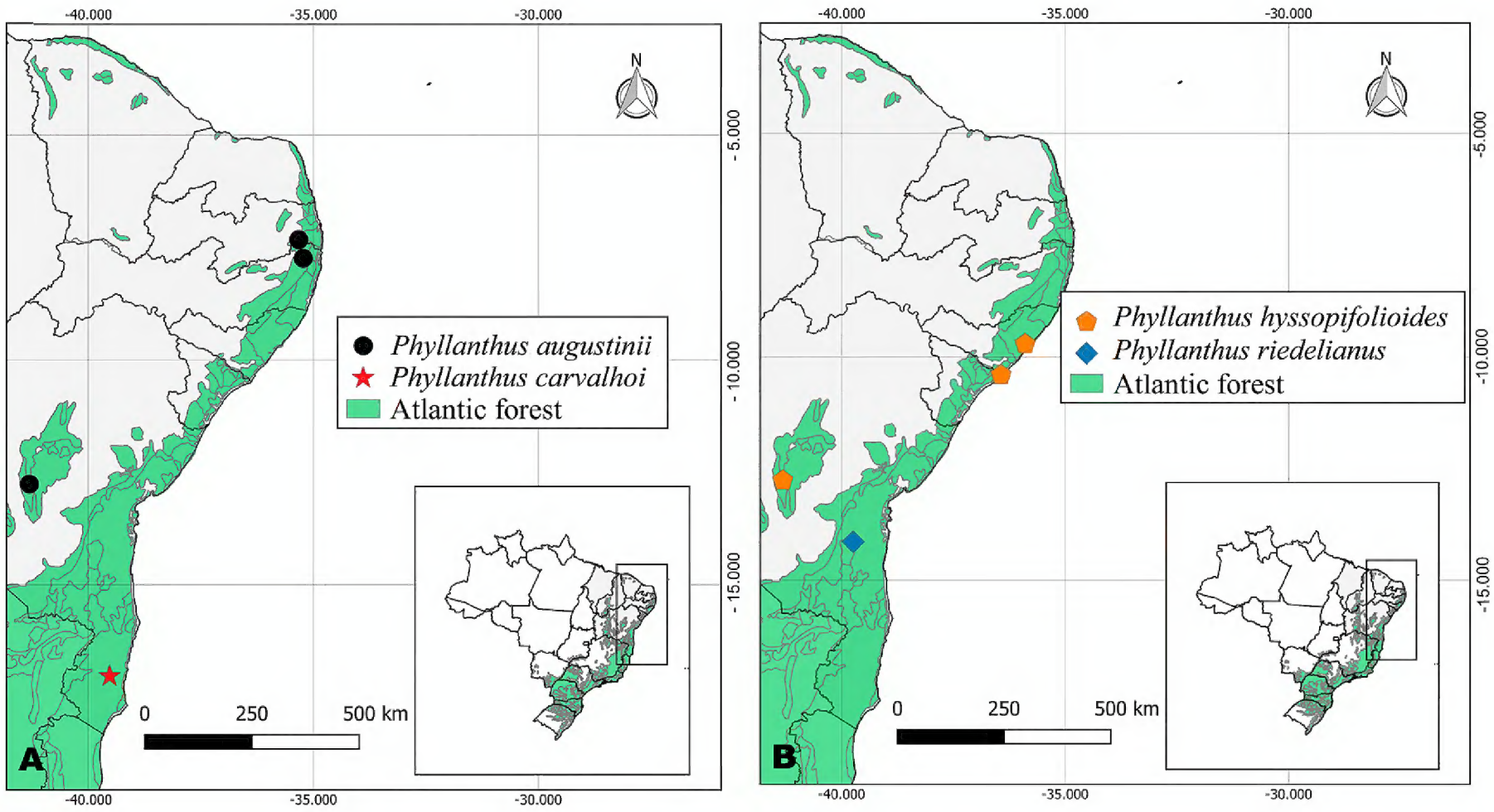

Figure 1. New occurrences of *Phyllanthus* in the northeastern Atlantic Forest (Brazil): **A.** *P. augustinii*, *P. carvalhoi*. **B.** *P. hyssopifolioides*, *P. riedelianus*.

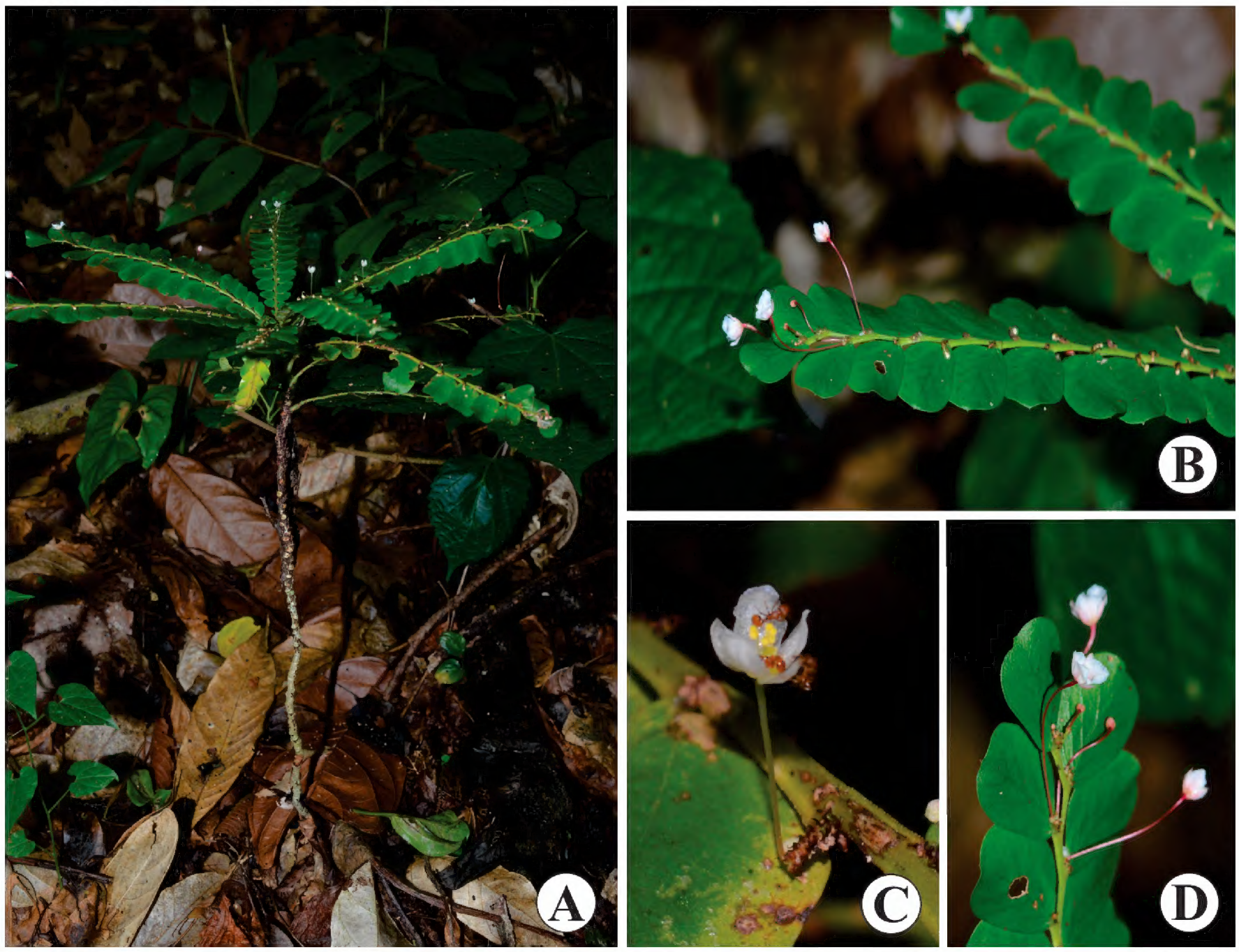

Figure 2. *Phyllanthus carvalhoi*. **A.** Habit. **B.** Branches, showing asymmetrical leaves and flowers with long pedicels. **C.** Staminate flower, showing the whitish pedicel and five sepals. **D.** Pistillate flower, showing vinaceous pedicel and staminate and pistillate sepals (*A.M. Torres 213*, PEUFR).

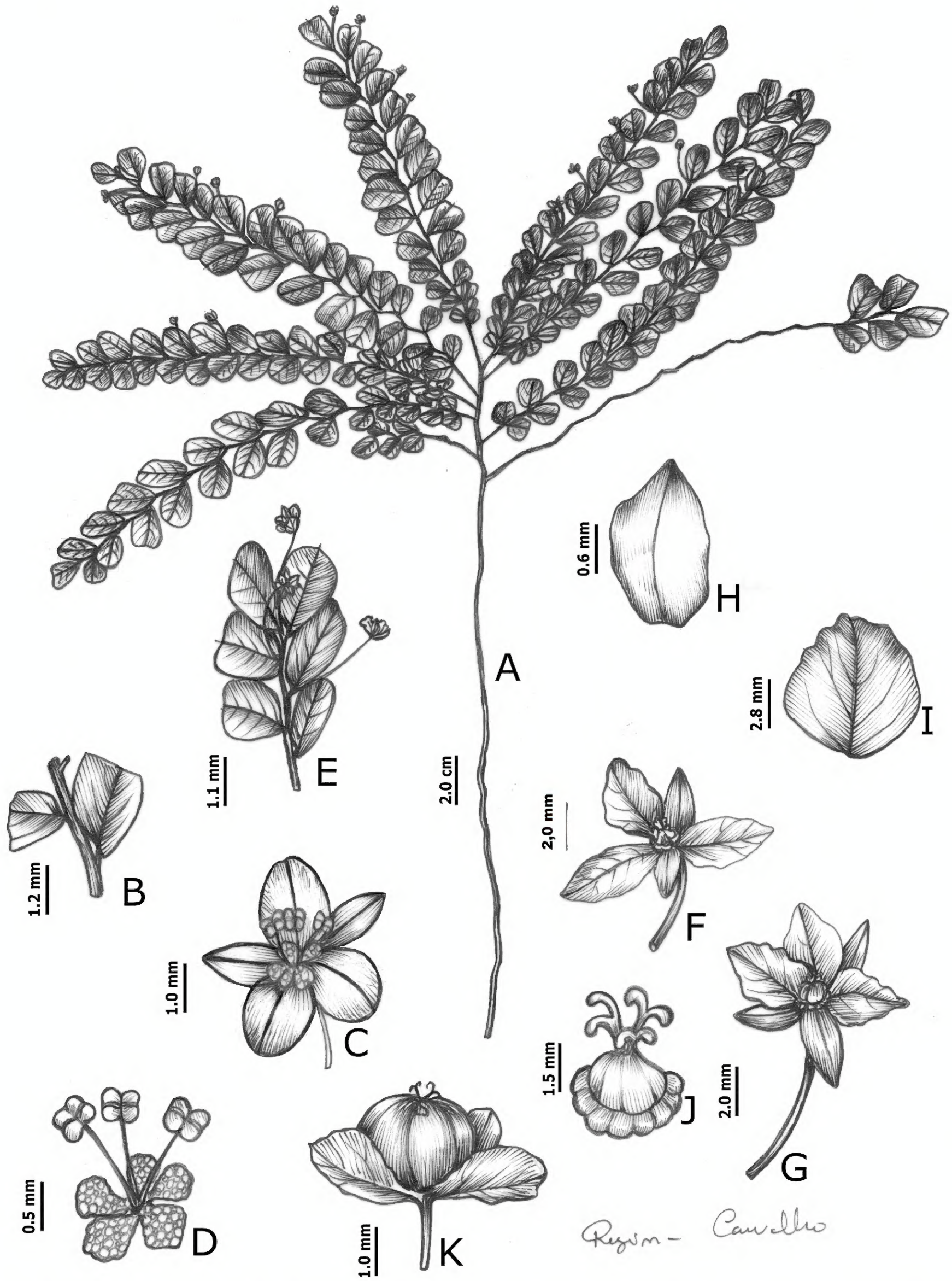

Figure 3. *Phyllanthus carvalhoi*. **A.** Habit. **B.** Leaf base. **C.** Staminate flower with five sepals. **D.** Stamens with verrucose disk. **E.** Reproductive branch showing elongated pedicel of pistillate flower. **F.** Pistillate flower with five sepals. **G.** Pistillate flower with six sepals. **H.** External pistillate sepal. **I.** Internal pistillate sepal. **J.** Ovary with nectariferous disk. **K.** Fruit with persistent calyx. *A.M. Torres 213* (PEUFR); *A.M. de Carvalho, R. Callellas & L.A. Mattos Silva 2022* (CEPEC; DAV; NY).

puberulent. Cataphylls absent. Stipules ca 1 mm long, triangular, margin entire, glabrous. Leaves sessile to subsessile, lamina 10–14 × 6–7 mm, present only on secondary branches, oboval to falcate, base asymmetrical, apex mucronate, chartaceous, slightly discolor, abaxial face papillary and adaxial face glabrous, margin entire, venation brochidodromous. Flowers solitary. Bracts ca 1 mm long, lanceolate, margin entire, glabrous. Staminate flowers with pedicel 3–5 mm long, filiform, whitish, glabrous, sepals 5, 1.5–2 × 1–1.5 mm, uniseriate, elliptical to obovate, apex slightly obtuse to rounded, with an evident greenish central vein, subchartaceous, margin

entire, nectariferous disk with 5 segments, obtriangular, verrucose, alternisepalous, stamens 3, 0.8–1 mm long, free, anthers with horizontal slits. Pistillate flowers with pedicel 14–18 mm long, filiform, vinaceous, glabrous, sepals 5 or 6, biseriate, internal sepals ca 4 × 2 mm, obovate to rounded, with pinnate veins, margin sinuate, apex obtuse; external sepals ca 2 × 1 mm, elliptic, with an evident greenish central vein, margin entire, apex obtuse, both sepals membranaceous, disk entire with sinuate margin, ovary ca 1.5 mm long, globose, smooth, styles 3, ca 1.3 mm long, free, bifid, stigmas lobate. Capsule globose, surface smooth, pedicel ca 2 mm long, glabrous. Seeds not seen.

Habitat and distribution. *Phyllanthus carvalhoi* is restricted to the southern Bahia Atlantic Forest and is known only for the municipality of Itamaraju, in the Pau-Brasil farm, where it is apparently limited to shady locations near streams between cocoa plantations. Both collections indicate that it flowers and fruits between May and November.

Conservation status. We classify this species as Critically Endangered, B1ab(iii,iv) + B2 ab(iii); D following IUCN (2012) criteria. We assume that this species is rare, as it is very infrequent at the type locality, where it is endemic and only ever collected. However, because it occurs only in an area with extensive cocoa plantations, it is at risk of extinction due to extensive deforestation for agricultural purposes and local resource harvesting of the forest. We believe that *P. carvalhoi* should be the focus of urgent propagule harvesting, introductions into protected areas in the northeastern Atlantic Forest, and *ex situ* cultivation efforts, to prevent its extinction.

Comments. In the original publication of *P. carvalhoi* Webster (2002) presented a diagnosis, general description, and photograph of the holotype but gave no illustrations. In studying the protologue we noticed that Webster focused on characteristics such as its large falcate leaves, with broad asymmetric base, and the long pedicels of the fruits to differentiate it from other species of *Phyllanthus* sect. subsect. *Clausseniani*. However, a more careful analysis of living specimens revealed characteristics not mentioned in the protologue that are likewise fundamental to distinguishing it, such as the presence of 5 or 6 biseriate pistillate sepals, with the internal sepals being wider with sinuate margins and pinnate veins, and the external sepals being narrower with entire margin and only one central vein, stigmas lobed, pedicel vinaceous in the pistillate flowers, and whitish in the staminate flowers. Based on this information and our analyses of other species of the group occurring in the Atlantic Forest, we found that *P. longipedicellatus* M.J. Silva shows numerous similarities to *P. carvalhoi*. It differs, however, as *P. carvalhoi* has glabrous to puberulous branches (vs densely pubescent in *P. longipedicellatus*), broader leaves 6–7 mm wide (vs narrower leaves 4–5 mm wide), a discreetly obtriangular staminate disk with a fully verrucose surface (vs broadly obtriangular with a verrucose surface only at the apex), and biseriate pistillate sepals (internal 5 or 6 oboval to rounded, and external elliptic) (vs uniseriate pistillate sepals with 5 elliptic sepals).

***Phyllanthus hyssopifolioides* Kunth**, Nov. Gen. Sp. (quarto ed.) 2: 108. 1817.

Type. Venezuela: Without locality, without date, *A.J.A. Bonpland & F.W.H.A. Humboldt*, s.n. (holotype, P00669937!).

New records (Fig. 1B). Brazil. Alagoas: Marechal Deodoro, Dunas do cavalo Russo, April 2009, *E.C.O Chagas & M.C.S. Motta 5411* (MAC 43907); Piaçabuçu, 23 May 1982, *R.F. Rocha & R.P. Lyra-Lemos 283* (MAC 5386); Bahia: Andaraí, Alagados Marimbus, 12°45′55″S, 041°18′52″W, 14 Apr. 2012, *E. Melo et al. 11100* (HUEFS 186379).

Identification. *Phyllanthus hyssopifolioides* can be differentiated from the other species of the genus by having leaves arranged on the main axis and secondary branches, elliptical to oval, flowers with six sepals (being oval in staminate flowers, and oval to elliptical in pistillate flowers), and staminate disk with six obtriangular segments. Among *Phyllanthus* species occurring in northeastern Brazil, it resembles *P. caroliniensis* Walter with whom it shares the same features indicated above, but it differs by having by oval to elliptical leaves (vs obovate in *P. caroliniensis*), staminate sepals ovate (vs obovate), and pistillate sepals ovate to elliptical (vs oblong).

Habitat and distribution. *Phyllanthus hyssopifolioides* is distributed throughout South America (Martins et al. 2014); it has been recorded in the northern (Amazonas, Para, and Roraima), midwestern (Goiás), southern (Paraná), and southeastern (Rio de Janeiro) regions of Brazil, in the Amazon, Atlantic Forest and Cerrado (Secco et al. 2015; Martins et al. 2014; Secco and Silveira 2016). We report for the first time in northeastern Brazil, specifically in the states of Alagoas and Bahia. In Alagoas, the species grows in restingas, and in Bahia in ombrophilous forest. The flowering period was from April to May in the study area.

Conservation status. The species has been assessed as of Least Concern, following the IUCN (2012) criteria.

***Phyllanthus riedelianus* Müll. Arg.**, Linnaea 32: 16. 1863.

Type. Brazil: "inter Taubaté et Mugi prov. S. Paulo", without date, *L. Riedel 1621* (NY00273120!)

New records (Fig. 1B). Brazil. Bahia: Ipiaú, estrada a Itagibá: 14°08′12″S, 039°44′27″W, 03 November 1970, *T. S. Santos 1267* (CEPEC 6231).

Additional specimens examined. Brazil. Rio de Janeiro: Nova Iguaçu, Reserva Biológica do Tinguá. Rebio, Tinguá picada do Macaco, próximo a ilha, 22°33′14″S, 043° 25′32″W, 12 November 2001, *H.C. Lima 5888* (HUEFS 195853)

Identification. *Phyllanthus riedelianus* can be differentiated from other species of the genus by having a shrubby habit, non-phyllanthoid branching, ovate to elliptical leaves with acuminate apices, axillary and glomerulate staminate inflorescences, staminate flowers with six sepals, three completely fused stamens, and anthers opening by vertical slits. Among the species that occur in the northeastern Atlantic Forest, it most resembles *P. acuminatus* in the features mentioned above; however, in *P. acuminatus* the branching pattern is phyllanthoid, with bipinnatiform branches, and anthers with horizontal slits.

Habitat and distribution. *Phyllanthus riedelianus* is endemic to Brazil, occurring in the Atlantic Forest domain from Minas Gerais to Santa Catarina states (Martins et al. 2014; Secco et al. 2015). We report it for the first time in northeastern Brazil, in ombrophilous forest in Bahia state. The fruiting period was in November in the study area.

Conservation status. The species has been designated as of Least Concern according to the IUCN (2012) criteria.

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Authors' Contributions

AMT designed the study and wrote the manuscript, made the collections, reviewed herbarium specimens, and made the identifications; SMAS contributed to the discussion, review, and approval of the final manuscript; JCRM contributed to wrote the manuscript; WPFSC made the collections, drawed maps and contributed to the discussion and MFS contributed to the correction and research funding.

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